the four poles. In multipole devices with larger numbers of poles, the increased number of poles enlarges the region of lower field, or region which is effectively field free. Also known in the art are ring electrode devices wherein the field free region is dictated by the diameter and the spacing between the rings. Ring electrode devices consist of conductive rings having approximately equal spacing between rings, and have confinement properties determined by the diameter of and the ring thickness which roughly corresponds to the properties determined by the rod diameter and spacing in multipole devices. The similar alternating phase of the RF voltages for each subsequent ring of such devices enables their use as "ion guides." Such devices are used far less frequently than conventional multipole ion guides.

Also known in the art are quadrupole mass filters which use DC potentials with quadrupole devices to discriminate ions according to their mass to charge ratio. In the absence of the DC potentials and in the presence of a low pressure gas, these types of ion guides do result in a reduction of the dispersion of the ions due to collisional damping of charged particles to the field free region. At higher pressures however, ion velocities may become too small for ions to rapidly exit the multipole, resulting in a build up of space charge and decreased ion transmission.

The nearly field free region is constant across the length of the multipole or ring electrode device and includes some fraction of the volume inscribed by the poles or rings. Given a fixed number of poles or rings, the nearly field free region may thus only be significantly increased by increasing the distance between the poles or rings and the diameter of the poles or rings, both of which require an increase in the RF voltage applied to the poles or rings to obtain effective confinement. Again, given a fixed number of poles or rings, the size of a cross section of the field free region, and thus the size of the region which accepts ions (or the ion acceptance region), increases as the square root of the RF voltage applied to the poles or rings. Thus, to create any significant gain in the cross section of the field free region, and thus the ion acceptance region, in practice requires prohibitively large RF voltages. Larger acceptance regions can also be obtained by the use of higher multipole devices, but a general failing of this approach is that the nearly field free region becomes correspondingly large and effective focusing to a small region is not obtained. Thus, the ability to focus ions through a small diameter aperture is reduced.

U.S. Pat. No. 5,572,035 to Jochen Franzen, entitled "Method and device for the reflection of charged particles on surfaces", describes a variety of configurations of strong but inhomogeneous RF fields of short space penetration for the reflection of charged particles of both polarities at arbitrarily formed surfaces. As described by the inventor, this device "is particularly useful for the guidance and storage of ions in a pressure regime below about 10^{-1} millibar, and with frequencies above 100 kilohertz. It may be used at normal air pressures for charged macroparticles." Thus, as described by the inventor, the invention of the Franzen patent is ill suited for operation at pressures close to atmospheric, where the transition from an ion source to an instrument having a low pressure region would be located, except for macromolecules, and only then through the use of audio frequencies. Such macromolecules, or macroparticles, are many orders of magnitude in both mass or mass to charge rations than analyzed by mass spectrometry.

Thus, there exists a need for a device which can both guide ions and focus a dispersion of charged particles at near atmospheric pressures.

SUMMARY OF THE INVENTION

Accordingly, it is an object of the invention in one of its aspects to provide a method for focusing, and reducing a dispersion of, charged particles in a pressure region at near atmospheric pressures. As used herein, "near atmospheric" pressures are defined as between 10^{-1} millibar and 1 bar. As used herein, the charged particles which are to be focused according to the present invention, are defined as being smaller than one billion AMUs. The focusing of the present invention is accomplished by providing an apparatus, hereinafter referred to as an "ion funnel", which is operated at near atmospheric pressures and which generates an RF field having a field free zone with an acceptance region and an emmitance region, where the acceptance region is larger than the emmitance region. The ion funnel has at least two members, each member having an aperture, such that the apertures are disposed about a central axis and define a region of charged particle confinement. The members, by way of example, can be formed as circular rings, wherein the interior diameter of the ring defines the aperture. Some fraction of this interior diameter defines the useful acceptance region of the device. However, the members and the apertures are not limited to circular forms and may take any shape. The first aperture, or entry, of the ion funnel is larger than the second aperture, or exit. A funnel shape is thus created by the boundaries of the apertures, which also defines the side or sides of the ion funnel. The size and shape of the entry and exit apertures, as well as apertures disposed between the entry and the exit, are selected to control the size and shape of a beam or cloud of charged particles (such as ions) directed through the ion funnel. A cross section of the funnel may be any shape, for example, round, square, triangular or irregularly shaped, and the shape of the cross section may vary along the length of the ion funnel. Thus, examples of desired shapes for the apertures of the ion funnel would thus include, but not be limited to, circular, oval, square, trapezoidal, and triangular.

The ion funnel has RF voltages applied to alternating elements such that progressing down the ion funnel, the RF voltages alternate at least once, and preferably several times, so that the RF voltages of adjoining elements are out of phase with adjacent elements. In general, adjacent elements may be out of phase with one and another by between 90 degrees and 270 degrees, and are preferably 180 degrees out of phase with one and another. Thus, an RF field is created with a field free zone in the interior of the ion funnel wherein the field free zone has an acceptance region at the entry of the ion funnel and an emmitance region at the exit of the funnel and the acceptance region is larger than the emmitance region. The RF voltages thus act to constrain charged particles within the field free region, and as charged particles move from the entry to the exit, the field free region decreases in diameter to confine the charged particles into a smaller cross section. Charged particles driven through the ion funnel are thus focused into a charge particle beam at the exit of the ion funnel. Ions so effected can be said to be "trapped" or "directed" by the ion funnel. Also, by varying the shape of the apertures, the shape of the resultant charged particle beam may be varied to correspond to a shape desired by the user.

It is a further object of the invention that the ion funnel be positioned within a chamber where ions generated at atmospheric or near atmospheric pressures are to be introduced into a device having the interior maintained at lower pressures. As such, it is preferred that the chamber containing the ion funnel be maintained at between 10^{-1} millibar and 1 bar, and it is especially preferred that the chamber containing the ion funnel be maintained at between 1 and 100 millibar.

It is a further object of the invention in one of its aspects to provide a method for driving charged particles through the